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Electric Railway Traction

The Glasgow Underground

AFTER 37 years of operation on the cable system, the Glasgow subway is about to enter on halcyon days with the coming of electrification. For the slow and noisy trains at four-minute intervals an electric service of the same intensity but operating to a schedule approximately 30 per cent. faster is to be substituted; the capacity of the line will be still further increased by the possibility of multiple-unit working. Among the vicissitudes of the line a capacity for earning respectable dividends has never been included, but even if no increase in passenger traffic accrues, it is estimated that the savings in operation brought about by electric traction will be sufficient to wipe out the present annual gross deficit of £30,000. To the present owners, the Glasgow Corporation, it is doubtful whether electrification will prove of financial benefit, for although the number of passengers will almost certainly increase, it will probably be only at the expense of the buses and trams, both of which are owned by the same authority. To the citizens of Glasgow, however, who have long forgotten the original humorous appeal of the cable system, electrification should prove a decided boon. It is in foggy weather that an underground line is of particular benefit, and Glasgow is subject to the same sort of palls as characterise a London winter. Further, the certainty of a given travelling time, by reason of the elimination of the traffic blocks of road transport, should weigh very heavily with workers in the city. The modernisation of the Glasgow subway also includes colour light signals, but these will be worked automatically. The old semaphore signals were hand-operated from the stations, and a train was given line clear for the whole section between its starting point and the next station.

A New Control System

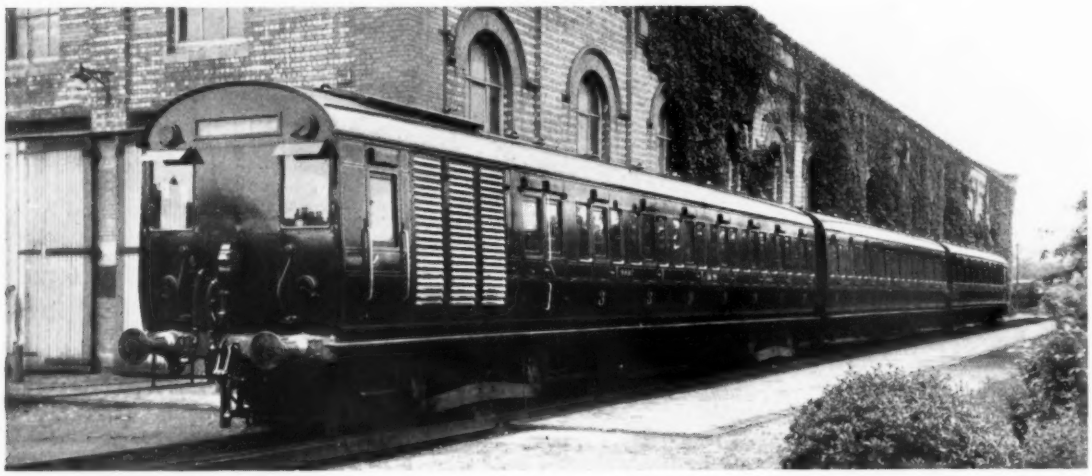
DURING recent months the London Passenger Transport Board has been experimenting at Acton with a new form of electric control known as the metadyne system which has some revolutionary characteristics. The metadyne itself is a special form of rotary transformer, and the apparatus installed in the two-car trial train of the L.P.T.B. was made by the Attercliffe works of Metropolitan-Vickers in conjunction with the inventor, Mr. Pesterini, but we believe that a similar system has been tried on one of the French railways. The function of the metadyne control is to convert automatically the constant voltage picked up from the contact line or conductor rail to constant current at variable voltage for supply to the traction motors. The principal feature of the system is that, as the above action is reversible, regenerative braking can be carried down to a dead stop. Experiments on the London Underground have shown that such stops can be made smoothly in conjunction, we believe, with a regenerated current equivalent to 30 per cent. of the normal consumption on frequently-stopping service. It is understood that switchgear contactors are eliminated, but the strong point from the London Passenger Transport Board's point of view must surely be the elimination of brake-shoe renewals, for the normal brake rigging need be only of a light character, as it is required only for the purpose of holding a train after stopping, or in sidings. Further experiments are to be made on a train consisting of three two-car units each fitted with metadyne control applied to four traction motors; this equipment is now being built tan-Vickers in conjunction with the inventor, Mr. Pesterini, by the Metropolitan-Vickers Electrical Co. Ltd. The results will be awaited with the keenest interest, for the question of retardation is, of itself, one of great importance to all densely-trafficked railways.

Technical Progress in 1934

DEVELOPMENT in the technical side of railway electrification has not lagged behind the increase in electrified mileage during the past twelve months, and the field of progress has been just as wide, as a perusal of the pages of the *Electric Railway Traction Supplement* will prove. The merits of standardisation on a large scale have been given recognition during the year on the Southern Railway in this country and on the Italian State Railways; in both cases traction motors have occupied a prominent place in the programmes, and in this one detail alone there are great possibilities of saving money without stultifying progress. Mercury arc rectifiers have been installed in increasing numbers, and so far as new d.c. schemes are concerned, it would appear as if the day of rotary converting apparatus was over. Metal-clad and glass-bulb rectifiers have each a distinct field of their own in traction service, more particularly as regards size, and remote-control can be applied with equal facility to either, and this feature of operation seems likely to progress rapidly in the future. The application of carbon-strip pantographs, the trial of steel overhead contact wires in sidings and on branch lines, and the improvements made in traction motor and control gear design have received detailed attention in this Supplement during the last twelve months. Progress in the use of light metals and welded steel, although not extensive, has been definite, and examples of aluminium and shot-welded steel trains are illustrated in another part of this issue. Towards the end of the year a tendency became evident to adopt streamlined forms of construction, even when the top speed was nothing out of the ordinary. For instance, the Netherlands Railways placed orders for triple-car articulated trains streamlined in a manner similar to the diesel-electric trains, and the Swiss Federal Railways decided to acquire a few light-weight motor coaches with a modified form of streamlining. In the first example the top speed is 62 m.p.h. and in the second, 78 m.p.h. No fewer than 57 streamlined locomotives of high power have been ordered by the Pennsylvania Railroad to run at speeds of 90 m.p.h. and over, and as a grand finale the Italian State Railways has just ordered six 6-car streamlined trains suitable for a top speed of 100 m.p.h. and a normal balancing speed of 88 m.p.h., which will include dining cars.

RAILWAY ELECTRIFICATION IN 1934

Conversion of steam lines and the construction of entirely new electric railways shows appreciation of the possibilities of electric traction in solving difficult operating problems



Three-car train of compartment stock as used on the Liverpool-Southport line

THE progress made in railway electrification during the past twelve months has been anything but discouraging. Fortunately, the possibilities of electrification are very widely appreciated and little difficulty appears to have arisen in raising the necessary capital, even for schemes of great magnitude.

It is pleasing to be able to record that British railways and British manufacturers have taken a considerable part in the progress which has been made. The extension of the Southern Railway's electrified main lines from Wivelsfield to Eastbourne and Hastings, and from Bickley and Orpington to Sevenoaks, were recorded in this Supplement exactly twelve months ago, and such progress has been made that electric traction over both routes to Sevenoaks will begin on January 6, 1935, and is expected to be opened to Hastings in May next. The short section from Bickley junction to St. Mary Cray was opened on May 1 last. Just a month ago, it was announced that the Southern intended to convert the Lewisham-Nunhead loop and the Woodside-Sanderstead line. When these schemes are completed, the Southern will have 447 route and approximately 1,160 track miles electrified, all on the 650-volt d.c. system.

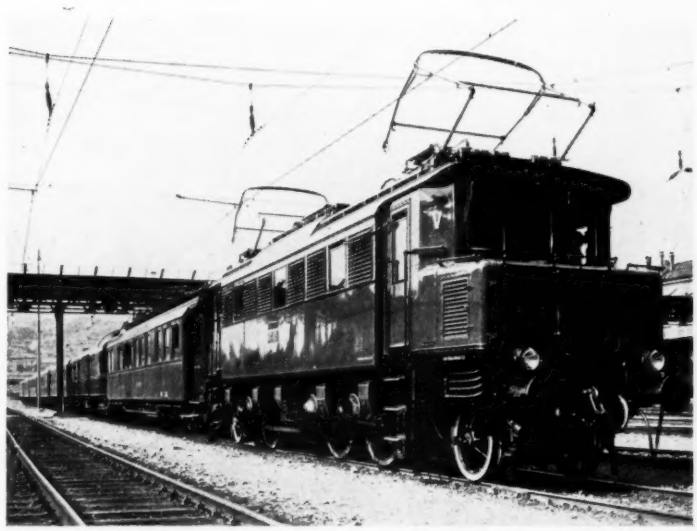
The vast programme of the Southern has tended to overshadow the proposals of the London Passenger Transport Board (announced in the issue of this Supplement for November 16) for the construction of a new tube between Baker Street and Finchley Road, and the electrification of the old Metropolitan double-track line from Rickmansworth to Amersham. Farther north, the L.N.E.R. has in hand an extensive modernisation of the Tyneside electrified lines, and the Mersey Railway has also inaugurated a modernisation scheme for providing better facilities between Liverpool, Rock Ferry and Birkenhead Park.

New station at Fredericksberg on the suburban electrified lines at Copenhagen

Overhead construction on a newly-electrified section of the Paris-Orleans Railway

Despite the £5,000,000 which has been spent on or allocated to railway electric traction in this country during 1934, the parlous state of the employment and railway financial questions on the Continent has given an impetus towards electrification proposals which, in France at least, are without parallel in the history of railways. The Marquet Plan, introduced by the Ministries of Finance and Public Works, provides for the expenditure by 1940 of 1,300,000,000 fr. on railway electrification, divided up as follows:—

Etat ..	403 million fr. for conversion of Paris-Le Mans line and certain suburban works as already detailed in the issues of this Supplement for July 27 and August 24.
P.O. Midi ..	470 million fr. for conversion of main line from Tours to Bordeaux; to be undertaken when the present electrification of the Vierzon–Brive line is completed. This is in addition to the electrification programme which the Midi has been carrying out for some years.
Est	400 million fr. for conversion of suburban lines from Paris as far as Chateau Thierry.
P.L.M. ..	27 million fr. for completion of the conversion work on the Culoz-Chambery section of the Mt. Cenis international route.

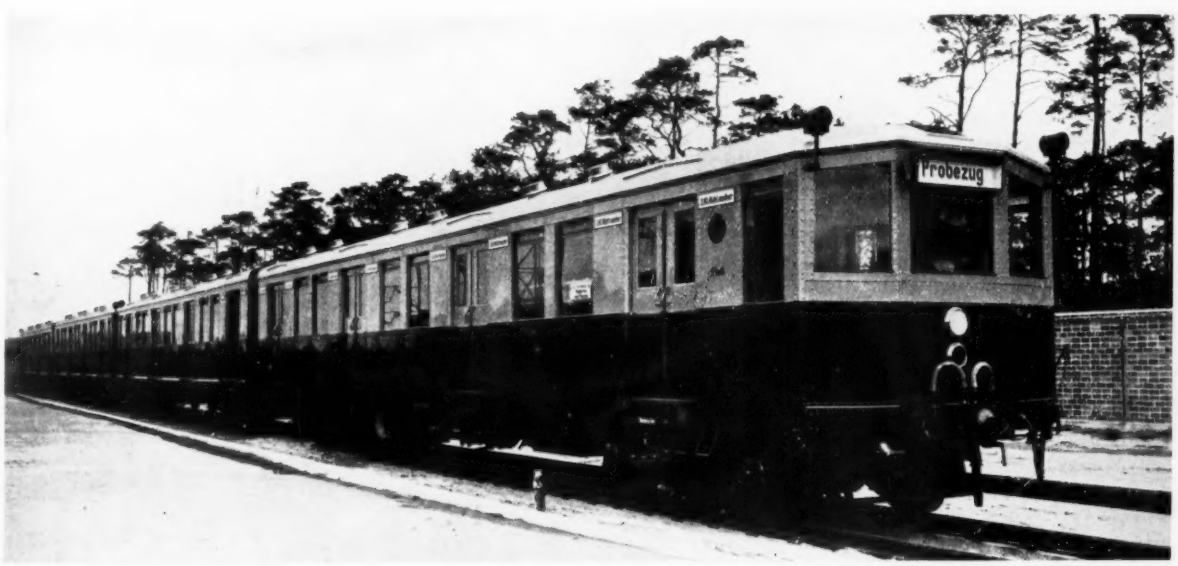


Express train on the Bavarian electrified section of the Reichsbahn

In Germany, the Reichsbahn on October 6 opened to high-tension single-phase electric traction the 54-mile double-track line from Halle to Magdeburg, in Central Germany, and also the 30-mile Tubingen-Plochingen line in Wurttemberg. Extension of the Bavarian system is now being carried out on the 86-mile line from Augsburg to Nuremberg. Lines totalling 111 route miles have been converted to electric operation by the Swiss Federal Railways in 1934, the principal sections being those from Berne to Lucerne, and from Rorschach to Buchs. Little has been done in Austria except to push forward the work on the southern side of the Tauern inclines, but in Hungary the conversion of the Komarom-Hegyeshalom section of the Budapest-Vienna main line has been almost completed. During the year, the Metropolitan-Vickers Electrical Co. Ltd. shipped to the Hungarian State Railways a large amount of substation and locomotive equipment.

Several important lines have been opened in Italy following the adoption of the 4,200,000,000-lire scheme for general electrification introduced by the Minister of Communications in 1933. Both high-tension d.c. and three-phase a.c. systems have been extended, the most important of the converted lines under the former being the Naples-Salerno, and under the latter the Bolzano-Trento and Trofarello-Cuneo sections. These works, however, were overshadowed by the opening of the entirely new Bologna-Florence Direttissima, which is operated on the 3,000-volt d.c. system. This line was described in the issue of the *Electric Railway Traction Supplement* for May 4.

Electrification is still proceeding apace on the lines of the Swedish State Railways, principally in the extension of the northern line from Hallsberg (on the Stockholm-Gothenburg route) to Krylbo and Aange, and on the west coast line from Gothenburg to Malmo. A beginning has also been made with the conversion of the line from



New train of aluminium-alloy cars on the Berlin suburban railways of the Reichsbahn

Laxaa on the Stockholm-Gothenburg line to the Norwegian frontier at Charlottenberg, and two private lines, the Bergslagernas and Dalsand Railways, have begun the conversion of 140 route miles, which includes the main line from Gothenburg to the Norwegian frontier at Kornsjo. It is possible that the next few years will see an all-electric route between Stockholm or Malmo and Oslo, for the Norwegian State Railways has announced its intention of proceeding with the electrification of the Ostfold line, a work which has been proposed for a number of years.

Suburban extensions of electric working were made during the year on the Copenhagen system of the Danish State Railways, and the Rotterdam-Dordrecht section of the Netherlands Railways was electrified. Good progress has been made with the conversion by British firms of the lines round Warsaw, and at long last a definite move has been made with the electrification of the Madrid-Avila main line of the Northern Railway of Spain. Main-line and suburban electrification schemes have been pushed ahead in Russia, but despite the desire to build everything in Russian factories, high-power electric locomotives have been delivered from Italy within the last few months. In Belgium, rapid progress is being made with the conversion of the Brussels-Antwerp line, which is to be opened before the Brussels Exhibition in 1935.

Extra-European Countries

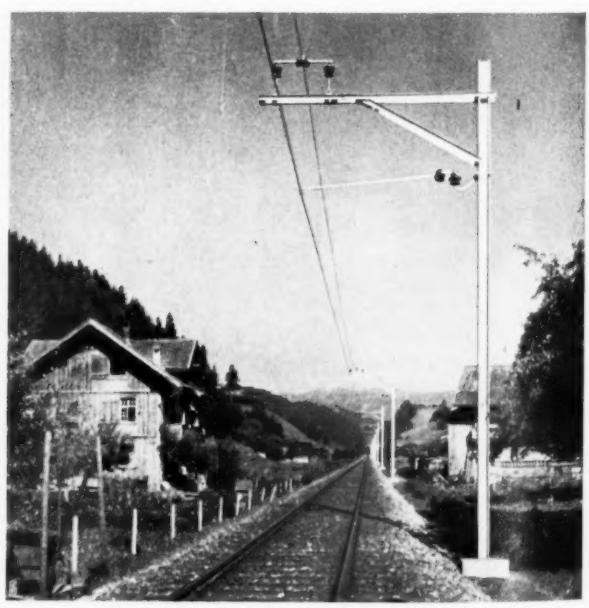
So far as British interests are concerned, the outstanding event of the year was the virtual completion of negotiations between the Brazilian Government and the Metropolitan-Vickers Electrical Co. Ltd. for the conversion on the 3,000-volt d.c. system of the lines of the Central of Brazil Railway from Rio de Janeiro to Barra do Pirahy and Santa Cruz, a route mileage of 93 and a track mileage of 232. The estimated cost is in the neighbourhood of £3,000,000, but no practical progress has yet been made, and apparently further difficulties have arisen.

Before the Granet Commission sailed for South Africa, the administration of the South African Railways had under conversion the Daimana-Harrismith section of the line from Natal to the Orange Free State, and this work is now almost completed. The administration also had under consideration the extension of electric working from Cato Ridge down to the sea at Durban, and this proposal was considered sound by the Granet Commission, which also recommended the extension of the northern end of the line from Glencoe to Volksrust, on the Transvaal border. Both of these lines are now being converted, but their working will not require additional generating plant or rolling stock.

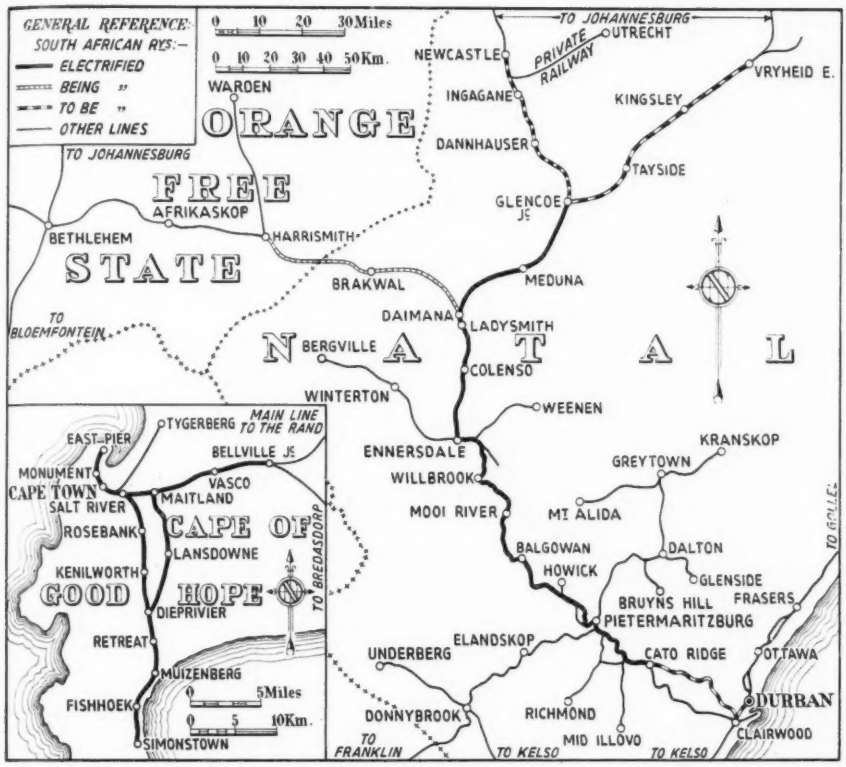
Electrification of steam lines has also been proceeding in a lesser degree in Japan, and authority has been given for conversion of further lines in Algeria. In North

Map of lines to be electrified in Poland

Passing station in the centre of the 11*-mile Apennine tunnel on the electrified Bologna-Florence Direttissima*



A view on the Berne-Lucerne section of the Swiss Federal Railways which was electrified this year



Map of electrified lines, South African Railways

America, the vast conversion programme of the Pennsylvania Railroad bestrides the narrow world of railway electrification like a Colossus. The project now nearing completion covers the electrification of all tracks between New York and Washington, a distance of 226½ miles. The electrification of the passenger tracks is now over 80 per cent. complete and the freight tracks approximately 50 per cent., and electric passenger operation is already in full swing over the 118 miles between New York and Wilmington, 27 miles south of Philadelphia. A number of lines in the Philadelphia, Newark and Trenton districts have been electrified for years, but the present programme comprised the conversion of 232 route and 1,082 track miles to the 11,000-volt 25 cycles single-phase system.

Technical Progress

What time the electrified railways of the world have increased in quantity, the quality of the equipment has also advanced. In point of mileage the increase in high-tension d.c. systems has been balanced by single-phase extensions, notably in Germany, Switzerland, and the U.S.A., and the relative merits of a.c. and d.c. traction stand very much where they did a year ago, or for that matter, two years ago. In d.c. traction, mercury arc rectifier substations appear as if they will become universal for new work, and a development of the rectifier, the mercury vapour frequency converter, has made its appearance in single-phase traction, on the Baden section of the Reichsbahn. Other interesting developments of the year have been the success of carbon wearing strips for pantographs and the trial of steel contact wires in sidings and lightly-trafficked branch lines.

Five of the nine double-bogie 100-ton, 2,400-volt electric locomotives supplied to the Harbour Commissioners Railway, Montreal

CONTROL EQUIPMENT FOR ELECTRIC SYSTEMS

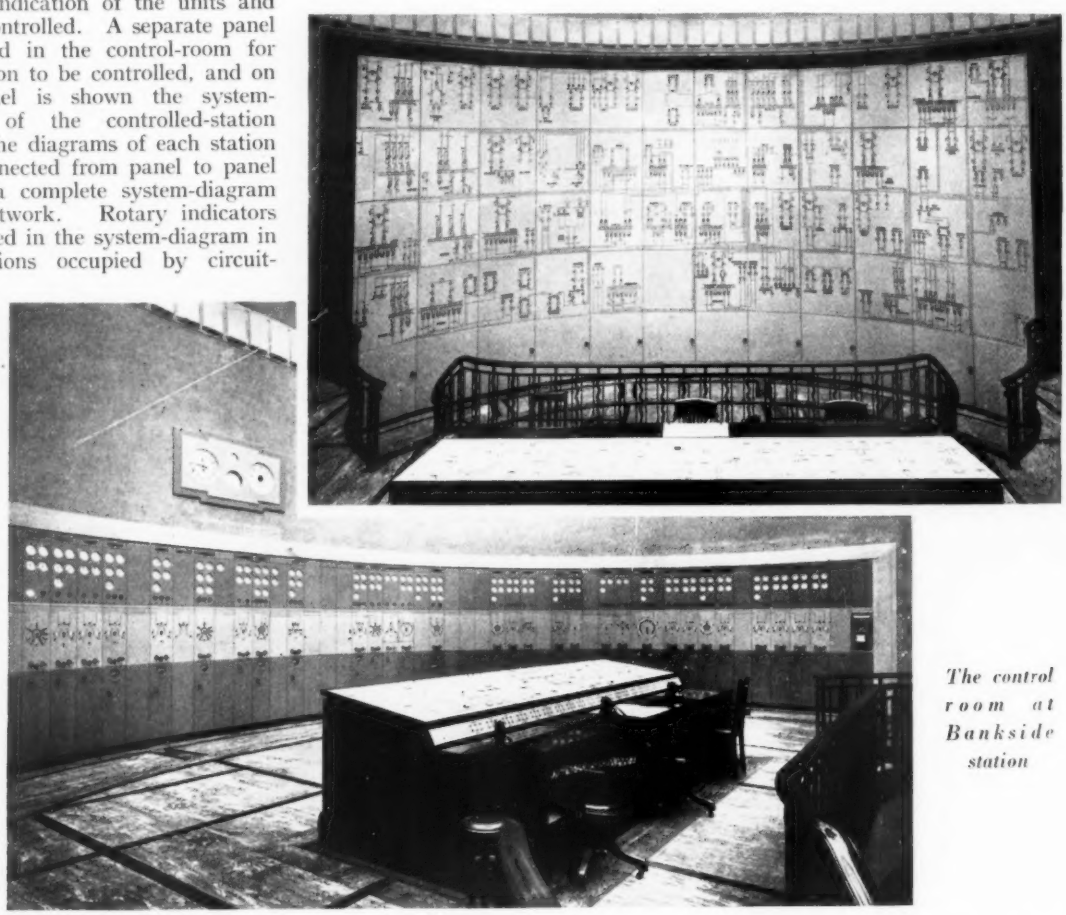
Centrovisory control and tallymetering apparatus as applied to electricity supply grids

AT Bankside, in London, is situated a control-room supervising the South-East and East England sections of the grid comprising 50 switching stations in the 132 and 60 kV. networks. Automatic indications, as detailed below, are received at Bankside from all these stations:—

(*a*) Condition of circuit-breakers (on or off).
(*b*) Position of transformer tap-changing equipment.
(*c*) Power transfer through the substation (megawatts and megavars), and direction of flow.
(*d*) Voltage of circuits at certain points.
(*e*) Total outputs of certain generating stations.
(*f*) Alarm on change under (*a*) or (*b*) with subsequent revised indication.

Reyrolle centrovisory-control apparatus is used to carry out this indication of the units and circuits controlled. A separate panel is installed in the control-room for each station to be controlled, and on each panel is shown the system-diagram of the controlled-station circuits, the diagrams of each station being connected from panel to panel to form a complete system-diagram of the network. Rotary indicators are inserted in the system-diagram in the positions occupied by circuit-breakers, and give an indication of their condition. These indicators show the condition of the circuit-breakers at all times, and when a circuit-breaker is operated at the distant station the indicator in the control-room is turned to indicate the new position of the circuit-breaker, and an independent audible and visual alarm is given. Meters and tapchange equipment position-indicators are also mounted on the panel, the latter continuously indicating the position of the equipment with an alarm on change. Meter-readings are initiated as required by the control-engineer, but when taken, the reading is locked on the meter, and in this way the logging of readings is greatly facilitated.

At each controlled station a centrovisory-control remote-station equipment is provided, comprising the necessary selector and signalling apparatus for sending the indications to the control-station. Centrovisory control has been designed especially for the control of power-networks, and every effort has been made to provide apparatus of the type familiar to power-station staffs. The system-diagram on the panels is unusual in that the diagram for each station is arranged on the appropriate panel in circular form. This method effects considerable saving in space, and also assists in the carrying out of the general principle of providing mechanised movements. The control-engineer's desk is fitted with a mimic diagram of the complete South-East grid scheme and interconnections to undertakers' networks. Hand-operated rotary indicators are provided to indicate the condition of the circuit-breakers on the system.



The control room at Bankside station

Tallymetering is the name given to a form of metering by which readings may be transmitted any distance over an electrical circuit, so as to give at a desired location readings that tally with the original indications. The principle on which the system operates is based on the

synchronised movements of two indicating pointers or their equivalent, one at the remote station and one at the control-station, the movements being started simultaneously and stopped simultaneously by means of signals transmitted from one station to the other. The apparatus consists of a transmitting-unit at one of the points, and a receiving-unit at the other. Both of these units are basically similar, comprising a pointer or arm driving over a meter-scale by means of a synchronous motor. The transmitter-unit has, in addition, a meter-movement operated by the quantity to be measured and mounted in axial alignment with the motor-driven movement.

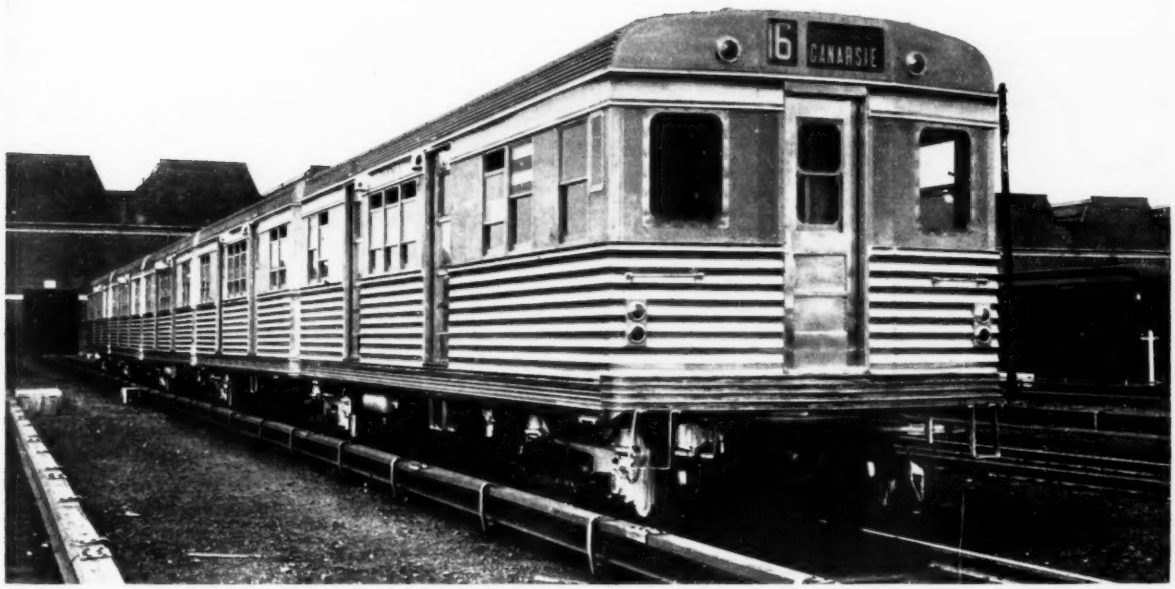
Both motor-driven pointers are started at the same time, and both are arrested when the remote-station pointer attains the value indicated by the meter-movement. The meter-pointer on the receiver-unit thus indicates the appropriate value, and is clamped in this position recording the last reading until a new reading is initiated.

Any form of indication or signal can be transmitted by means of this system, the following being typical examples:—

(*a*) Reading of any electrical meter (amp., volts, watts, volt-amp.).
(*b*) Indication of water-levels.
(*c*) Indication of transformer-tap positions.
(*d*) Engine-room signalling.

For the three latter indications the position of the transmitter may be set mechanically or by hand. A meter movement is not required in the transmitter, and the system is known as the tallygraph system, although it is in general similar to tallymetering.

A NEW TYPE OF SUBURBAN TRAIN



The Brooklyn-Manhattan Transfer Corporation has recently acquired two five-car articulated electric trains for suburban service which are built of stainless steel fabricated on the Budd shot-welded process. Each train is propelled by twelve 70 h.p. G.E.C. motors, and the seating capacity is 170 and the standing capacity 470. The overall length is 168 ft. 6 in. and the tare weight 71·5 tons

ELECTRICITY SUPPLY BILL AND THE RAILWAYS

In the House of Commons on November 29, Mr. Hore Belisha, the Minister of Transport, in moving the second reading of the Electricity (Supply) Bill, the main provision of which, apart from clarifying and amplifying the original Act of 1926, is to empower the Central Electricity Board to supply electricity direct to the railway companies, recalled that the Lord Weir Committee, on whose report the Act of 1926 was based, while considering that the subject of railway electrification was outside its terms of reference, could not refrain from observing that—

> "The availability of ample supplies of cheap energy from the 'grid-iron' would also relieve the railway companies from the necessity of heavy expenditure for power stations. At the same time, a railway demand for energy, which might approximate to 20 per cent. of the whole national demand for other purposes, would most favourably affect the national load factor, and thus reduce further the cost of energy."

Mr. Hore Belisha said the Government, at a later stage, decided to penetrate more deeply into the considerations which weighed with the Committee at that time, and accordingly they joined to Lord Weir the assistance of Sir Ralph Wedgwood and Sir William McClintock, and he ventured to say with confidence that anyone who had read their cogent and stimulating report must find that the provisions of Clause 4 of this Bill were amply justified.

"I have received a letter from the Railway Companies' Association," added the Minister of Transport, "informing me of the great importance which they attach to the passage of this Clause, and stating quite categorically that if any further schemes for the electrification of the railways are to

be entertained, the Companies consider it essential that they should have power to negotiate with and obtain their supplies of electricity direct from the Central Electricity Board."

This clause thus in no sense prejudiced the question of the electrification of the railways. It only provided that where a railway company decided to electrify its lines, it should be able to make a single contract covering its whole system.

Mr. Parkinson, speaking for the Labour Opposition, said that in the near future the electrification of railways must be seriously considered, and urged forward. Combined efforts by the railway companies and bulk supplies of electricity direct from the Board were the two things needed to achieve success.

Sir Geoffrey Ellis, as a critic of the Bill, said that so far from main-line electrification being probable, it was not at all unlikely that the other forms of traction, which were now being carefully examined on the various railways, might get rid of the necessity for traction by electricity except for comparatively short journeys.

Mr. L. Amery said the Southern Railway, of which he was a director, had been a pioneer in the matter of electrification. He submitted on the issue of general principle there was a very considerable distinction between the ordinary private individual or limited liability company operating in a particular area and the nation-wide system of the railways, which were great public utilities like the grid itself, and which, like the grid itself, were statutorily controlled. The grid system and the railway system were extended parallel throughout the whole country. The electrification carried out by the Southern Railway had been directly with the grid. The railway made itself, or got the grid to make, the necessary transmission lines and connections, and it drew its current from the grid, and had nothing whatever to do with the local undertakings. Where the snag came in, and where the difficulty arose, from which this Bill would liberate them, was that before the railway company began electrifying its own line it had to negotiate separately with every one of the electrical authorities whose area it traversed in the operation of its system. The Southern Railway was able to deal with seven different authorities in its main extension and had now to deal with four more authorities for the relatively small extension to Hastings. But the varying demands of the different authorities and their difficulty in understanding the problem was such that matters had practically come to a deadlock, and had it not been for the intervention of the Minister of Transport and of the Electricity Commissioners, the scheme might have been held up almost indefinitely.

Sir Charles Barrie said that if it should be that the L.N.E.R. and the L.M.S.R., with two main trunk systems connecting Scotland and England, after having decided for main line electrification, tried to make contracts with 200 or 300 different authorities, look at the difficulties there would be. The railway companies in supporting this Bill, had no desire to cut out the smaller electricity companies. Their sole desire was that when they came to main line electrification, if indeed, they ever came to it——

An Hon. Member.—They never will.

Sir C. Barrie.— The hon. member seems to know. At the moment, at any rate, I do not think there is any intention on the part of the main line companies to go in for big schemes of electrification. But if they did, it would be better if they could make a contract with one authority.

Mr. West said it was estimated by the Weir Committee that £260,000,000 would be the cost of electrifying the whole railway system, and he thought that expenditure would be one of the biggest investments that this country could undertake.

Alternative Forms of Traction

Mr. R. K. Law asked whether the solution of cheaper transport on the railway system might not lie rather in the direction of the diesel electric train and not line electrification.

Sir Robert Horne said that the railway companies were not being compelled under this Bill to do anything. All this Bill provided was that if they wished to electrify they should have those particular facilities. That was not to say that any railway company had not a free choice as to whether it should go in for diesel engines or electrification. Every railway company was calculating out those very things, and they were not shutting their eyes to the possibilities of lower costs from diesel-engine traction. A railway company was not entitled on its own responsibility to generate electricity for itself There was no way of telling in advance what the cost of any scheme of electrification was likely to be under the existing arrangement of having to negotiate with many different undertakings with different tariffs. Surely the companies must get rid of absurd clogging conditions of that kind.

Major Hills and Lord Burghley emphasised the importance of the Bill for railway companies, and the Bill was given a second reading without a division.

Mr. Emmott and others who had pressed without success for the Bill being sent to a Select Committee, opposed the Government motion for the consideration of the measure by Committee of the whole House, and their motion was negatived by 113 votes to 27.

In Committee of the House of Commons on December 5 on the Electricity (Supply) Bill, Mr. Herbert Williams, in consideration of Clause 4, which provides for direct supply of power by the Central Electricity Board to railway companies, moved an amendment to provide that the Board should not give any special terms or preferential rates to the railway companies. He contended that the companies were not so much concerned in this Bill about prices as about the problem of negotiation, and in any case there was no justification for giving lower rates to them at the expense of other consumers.

Mr. L. Amery held that the companies were entitled to lower rates for exceptional bulk purchase, and these not necessarily mean a loss to other consumers.

Mr. R. K. Law complained that the Bill was making the Board a direct competitor with undertakings in their own area and might sell electricity below the cost of production.

Mr A. C. Reed asked if the definition of a railway company in this Bill included railways belonging to coalfields.

Mr. Hore-Belisha, the Minister of Transport, said that to alter any phrase in this Bill could only be changed by sacrificing the main principle of the measure. It was in the national interest that the railway companies should, if they desired to electrify, be able to make one single bargain, and there was nothing unusual for an undertaker to make an exceptional price for an exceptional customer.

The Attorney-General, pressed for a definition of the Bill, referred Mr. Reed to the Railways Act.

The amendment was negatived without a division.

Sir Joseph Wall moved an amendment to provide that the Central Electricity Board should impose charges that would cover any extra expenses that supply to railway companies might involve. He said that not a single railway electrification scheme was held up or prejudiced by the existing system of electricity supply. The Southern Railway Company had one of the biggest electrification systems and other companies could proceed without any change in the existing methods of supply. The Weir Report was based upon the fallacy that electrification was the most economic form of traction. He believed the railways were being brought into the Bill to conceal its real object. It was all hypocritical humbug the talk about railway schemes of electrification, which did not exist.

This amendment was withdrawn as also was one by Mr. H. G. Williams proposing that electricity from the Board should be subject to the same conditions for locomotive and other works as traction power.

Mr. Hore-Belisha explained that he had, however, under the original Act to decide whether or not electricity supply for traction should be used for other purposes.

The Committee stage, with many amendments on the paper, was uncompleted when the debate was adjourned.

GLASGOW SUBWAY ELECTRIFICATION

The only non-electric underground railway in Britain has been converted in an endeavour to turn deficit into gain and provide a better service

Partick Cross station on the Glasgow cable subway

FOR nearly four decades the City of Glasgow has been served by a method of urban transport which is probably unique, viz., an underground line worked on the cable system. Incorporated in 1890 as a private concern—the Glasgow Subway Railway Company—the line was opened to traffic on January 21, 1897; it connects the north and south sides by a roughly oval line of 6½ miles, double throughout. After many years which were unsuccessful from a financial point of view, the directors in 1922 decided to close the line, but for a few weeks the Glasgow Corporation paid £200 a week to assist in reducing the working loss; however, on March 25, 1922, the line was closed. From July 2 of the same year the Corporation agreed to bear all loss, and the line was reopened; the ownership passed to the Glasgow Corporation in August, 1923, and the line has since been operated by the Transport Department of that body.

Several times within the past decade the electrification of the line was mooted, but it was not until about two years ago that a short section of the line was fitted up in order to test out the possibilities of electric traction. Trials having proved satisfactory, it was decided to equip the whole line, and this conversion work is now so far ahead that it is hoped to begin an electric service in one direction in January. By courtesy of Mr. L. Mackinnon, General Manager of the Glasgow Corporation Transport Department, we recently inspected the line and its equipment in the company of Mr. W. R. Bruce, the Subway Manager, under whose direction the work of conversion is being carried out.

The Cable Railway

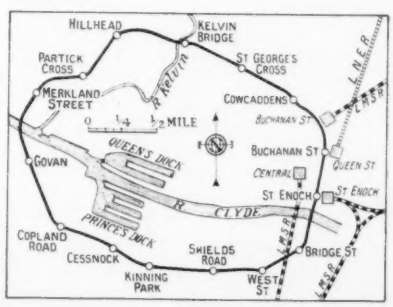
The cable system consists of a double line, with each track in a tunnel of its own, except at the stations, all of which are of the island platform type. The trains pass each other on the right and the counter-clockwise line is known as the inner circle and the clockwise track as the outer circle. The route mileage is 6·5 and as there are no points, crossovers, or sidings of any description, the track mileage is 13·0. The accompanying map shows the route; the workshops are situated at Govan, between Copland Road and Govan stations and the line runs beneath them. At this point the two tunnels run into a pit located in the erecting shop, and the cars are lowered to and raised from the appropriate track by an overhead traversing crane.

The cable-hauling equipment is at Scotland Street and consists of two 1,500 b.h.p. steam engines, one of which is used as a standby. The cables run over pulleys between the 60 lb. flat-bottomed rails, which are laid to the unusual gauge of 4 ft. Curves of 5 chains radius are numerous, and the line rises to and falls from each station at a nominal gradient of 1 in 40. Where they pass beneath the Clyde, the tracks rise and fall at a slope of 1 in 20.

On an average over 14,000,000 passengers a year are carried on the subway and the annual revenue is about £66,000 compared with an operating expenditure of £83,000. The cable trains consist of two double-bogie cars which run at a schedule speed of 9·73 m.p.h. Works trains are hauled by an 0-4-0 electric battery locomotive having a single traction motor and rod drive; the battery itself is of the Chloride type. There are three fares: ½d. for one station, 1d. for two stations, and 1½d. for three stations or over. Joy riding round the circle for 1½d. a day is prevented by the conductor of the train who examines and punches the tickets, which, however, are issued at turnstiles at the entrance to the station.

The Electrified Line

As an endeavour to reduce both the operating and gross deficits and also to provide a better service for the public, electrification was authorised at a cost first estimated at £94,000, but later increased to about £120,000 as a result of Ministry of Transport requirements regarding the reconstruction of the stations in order to make them fireproof. Details of the expenditure and savings got out by Mr.



Map showing the location of the Glasgow cable subway which is now being converted to electric traction

Mackinnon when the conversion was being investigated are as follow:—

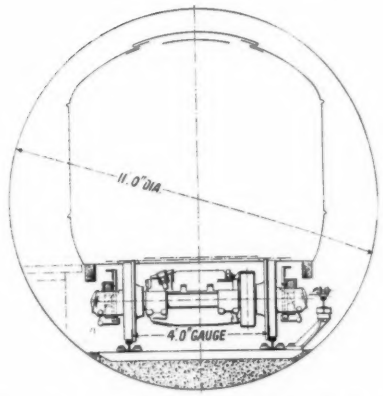
	£	£
Relaying track and installing third rail—		
Cost per mile—		
Material	2,000	
Wages	1,500	
Total	£3,500	
13 miles of track at £3,500 per mile		45,500
Reconditioning rolling stock—		
Cost per train—	£	
Material	1,350	
Wages	150	
Total	£1,500	
20 trains (motor coach and trailer) at £1,500 each		30,000
Distribution cables and switchgear in tunnels—		
Cost—	£	
Material	7,600	
Wages	1,400	
Total	£9,000	9,000
Feeder cables from substations		5,000
Extension of car sheds for storage of rolling stock		3,500
Automatic train signalling equipment		1,000
Reconstruction of stations		26,000
Total		£120,000

The estimated savings of electric operation are as follow:—

	£
Gripmen and conductors	8,000
Cleaning and oiling	500
Uniforms	50
National insurance	200
Superannuation fund	200
Cables and track sheaves	9,700
Cars	1,500
Electric lighting and power	1,000
Power expenses	7,000
	£28,150

These figures are based upon the same fares and same number of passengers as on the present cable system.

As far as supply of power is concerned, the electrified subway virtually forms an extension of the Glasgow tramway system. Current is obtained from the Corporation power station at Pinkston, and converted to direct current at 550-600 volts in three rotary-converter sub-stations located at Dalhousie, Kinning Park, and Partick Cross, which already supply the tramway; additional plant has been installed at these stations for feeding the subway.

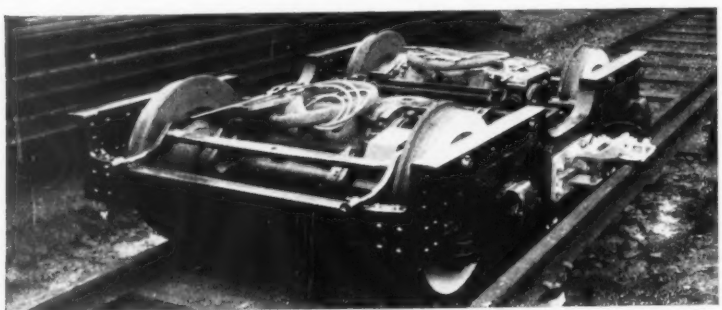


Section of tunnel on the Glasgow subway shows relation of the electric stock and third rail to the tunnel lining

The old 60 lb. running rails have been replaced by others of 80 lb. section, and the best of the old rails are being utilised as the third rail over a portion of the line. Owing to the limited diameter of the tunnel, the underside of the sleeper ends had to be shaped to the contour of the lining. As the conductor rail has of necessity to be at a relatively considerable distance from the running rail in both the vertical and horizontal directions, it was felt that the wooden sleepers would not be able to give the required support to the conductor rail supports, and steel sleepers therefore have been introduced beneath the conductor rail insulators, that is, every fourth sleeper is of steel, Colville's Limited being the manufacturer. One of the diagrams accompanying this article shows a section of the tunnel with the third rail and an electric car *in situ*.

Rolling Stock

The 40 existing cable cars are being rebuilt at Govan into 20 motor coaches and 20 trailers; with the cable



Left: Driving bogie for electric motor coaches running on 4-ft. gauge lines

Below: General view of one of the electric cars rebuilt from the old cable cars on the Glasgow Corporation subway

system a 4-min. service on each circle is maintained by 9 two-car trains with one set in reserve, but due to the higher speed of the electric trains the same service can be maintained by 6 two-car sets on each circle. Multiple-unit operation has been arranged for in the new stock.

Motor coaches and trailers are each 41 ft. long and have seating accommodation for 42 passengers and a standing capacity of 50; a two-car train can thus carry about 180 persons. Entirely new steel underframes and driving bogies were required, and these have been constructed by Hurst, Nelson & Co. Ltd., although embodied in the cars at the Govan works. The wheel diameter is 27 in. and the maximum speed 30 m.p.h.; the motor coaches tare 16·85 tons and the trailers 9·35 tons, giving a weight per seat for the whole train of 705 lb., and a weight per passenger of 327 lb. The vehicles are braked on the Westinghouse system, with one Ferodo-lined block to each wheel. They are coupled together by a central link and pin, and have end doors with a hinged connecting platform.

The Metropolitan-Vickers electrical equipment consists of four nose-suspended traction motors with electro-pneumatic multiple-unit control fitted with a dead-man handle device. A low-tension 110-120 volt circuit is used for operating the control and auxiliary mechanism. The cars are lighted electrically from two different supplies, so that the risk of a train being in darkness is very remote. Half the lamps are lit by the system now in use for the cable cars, that is, by collecting low-tension current from a wire running along the side of the tunnel, a collector being fitted to the side of the body for this purpose. The second half of the lamps are fed from the 550-600 volt traction circuit and are run six in series.

The driving position is at the leading end of the motor coach, but as the side gate at this end is used as an exit for passengers, the controls are grouped in a corner on the off side. They comprise the controller with control-cum-dead man handle, and a reverser; air brake handle; hand brake; and gate-switches. As may be seen from the illustration of the car, grille-gates are used at each end of the vehicles; they are worked by G. D. Peter's air motors and a system of levers operated through push buttons by the conductor. But as the driver may at certain times have occasion to alight in the tunnel, a switch for the adjacent gate is fitted on the side wall at the driving position. The cars are painted red from the waist line to the bottom of the window frames, with cream above and below.

Colour-light signals have been installed, and are to be operated automatically by the trains themselves. Under the cable system these signals are worked by hand from the stations, and a train is signalled direct from one station to the next. When a section between two stations is occupied, lamps are lit right through the tunnel section concerned, these lights being operated in conjunction with the train lights from the supply wire on the tunnel side. As it is possible for a train to be running without lights, a treadle outside each station actuates the tunnel lights as the train passes over it and makes contact.

Although the signals are hand-worked, they are connected to ramps which strike a trip cock attached to the bogie should the train pass the signal at danger; this shuts off the current and applies the air brake.

With the present service—beginning at 6.30 a.m. and ending at 10.50 p.m.—the car miles per annum amount to 1,091,000, and the car-hours to 112,000. A similar service maintained by 6 two-car trains on each circle would be equivalent to a yearly mileage per car of over 45,000. Although the actual date of the inauguration of electric traction may be governed by the reconstruction work on the stations, a full service will be in operation on both circles by the late spring. The figures of working expenditures and savings given earlier take no account of any increase in traffic, but there is little reason to doubt that the speedier and more satisfactory service provided by electric traction will appreciably increase the number of passengers carried.

The 7,200 h.p. electric locomotive built by Oerlikon and the Swiss Locomotive Works for express service on the St. Gotthard line of the Swiss Federal Railways. The maximum speed is 62 m.p.h. and the weight in working order 241 tons

TESTING FOR EARTHS, OPEN AND SHORT CIRCUITS IN ELECTRIC MOTORS

By CYRIL SYLVESTER, A.M.I.E.E., A.M.I.Mech.E.

MANY of the faults which develop in railway electrical equipment, such as motors and motor starters, can be repaired on site, because most of the faults are not of great consequence, although sufficiently serious to put a machine out of action. The reason why they are sent to the repair shops is because the essentials of testing are not understood. There is no reason why any electrical fitter in charge of a number of motors in any area should not do his own testing and fault locating. More often than not it will be found that an earth is confined to a slight breakdown of insulation at a point where it may easily be renewed; or an open circuit may exist in a machine which, on examination, will be found easy to make good.

Drop Test

All that is necessary is to understand one test thoroughly; this is the drop test, a generally accepted intricate test, but one which is really simple once its essentials have been mastered. It is not even necessary to obtain special equipment, as there are sufficient instruments on any switchboard to enable it to be carried out.

The chief essential of the drop test is to correctly interpret any readings which may be obtained on either a milli-voltmeter or milli-ammeter. In this respect an ordinary shunt ammeter can be used to function as either. The shunt must, however, be removed so that the needle of the instrument is very sensitive.

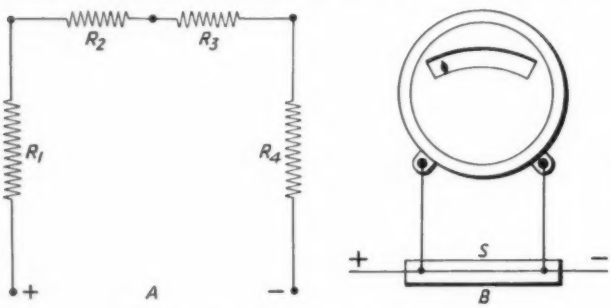


Fig. 1—Circuits illustrating drop test

The first step towards the explanation of the drop test is to show exactly what occurs in a circuit containing a number of resistances in series. Such a circuit is illustrated in Fig. 1 (A), where R_1, R_2, R_3 and R_4 are the resistances. If it is assumed that each of these resistances have the same ohmic value, it can be readily seen that, if the positive and negative points are connected up to a source of supply voltage, there will be exactly one-fourth of the applied voltage lost in each resistance. If, however, their ohmic resistance is not the same, there will be a different drop of volts in each resistance, according to the respective resistance values.

Assuming that the resistances are 1, 2, 3 and 4 ohms respectively, and that they are connected across a tension of ten volts, the total resistance is 10 ohms; this, connected across ten volts, enables one ampere to pass through the circuit. But although the current through each resistance is the same, the drop of volts in each is different, being 1, 2, 3 and 4 volts respectively.

Considering Fig. 1 (A) it may be assumed that the resistances are the shunt field coils of an electric motor. The resistance of each *healthy* coil is approximately the same as the others, so that the drop of volts across each coil would be the same. If it is found that the drop of volts across one coil is *lower* than the others, it is an indication that a short circuit exists in this coil, as a lower voltage drop means a lower resistance. If the ratio of this drop, to a healthy drop, is considered, the exact point of the short circuit in the coil can be determined.

Shunt Ammeter

The determination of an open or short circuit in the armature of a traction motor is not quite so simple. Here, the instrument for testing is either the milli-voltmeter or milli-ammeter. The characteristics of this instrument can be seen by a consideration of Fig. 1 (B).

Here an ordinary shunt ammeter is shown, S being the shunt. The deflection on the ammeter scale when current is passing through S depends upon two factors, the resistance of S and the current passing through S.

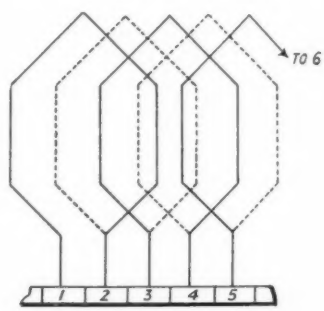


Fig. 2—Diagram of armature windings to illustrate method of locating a short circuit

It is, of course, assumed that the resistance of the leads connecting the meter to S is constant. If S were removed, and replaced by another shunt having a higher or lower resistance, it would not affect the amount of current passing through the shunt. The deflection on the meter scale would, however, be different because the altered resistance causes a different voltage drop across S. From this it will be seen that if the ammeter is disconnected from its shunt, and connected across any part of a current-carrying circuit, the voltage across that part of the circuit will be indicated on the ammeter scale.

Locating a Short Circuit

Applying this reasoning to the location of open and short circuits in a motor armature, and taking first the case of a short circuit, it will be seen that in Fig. 2 the first four coils of an armature winding are shown opened out for the sake of simplicity. Alternate coils are shown in full and dotted lines to make their progression quite clear. The coils are connected up to commutator segments numbered from 1 to 5. This diagram shows a portion of a lap wound armature, the ends of the first coil being connected to segments 1 and 2, the second coil to segments 2 and 3,

and so on. It will be seen that if a suitable voltage is supplied to segments 1 and 5, current will pass through four coils in series. The resistance of each coil is exactly the same, and, since the current through each coil is the same, an ammeter connected across any pair of adjacent commutator segments should indicate the same drop of volts.

If the reading across segments 2 and 3 is lower than that obtained across any other pair, this is an indication that a short-circuit exists in the second coil. If the deflection is only slightly lower, it may be taken for granted that only one turn of the coil is short-circuited. If, however, there is a zero reading (while making sure that current is passing through the coils), it may be assumed that the whole of the turns in the coil are short-circuited, probably at the back of the commutator segments.

Locating Open Circuits

Again considering Fig. 2, it will be seen that, if there is a distinct break in a coil, no current would pass through the coils on voltage being applied to segments 1 and 5. In this case there would be no reading on the ammeter scale until the meter is placed across the segments to which the ends of the broken coil are connected. Here

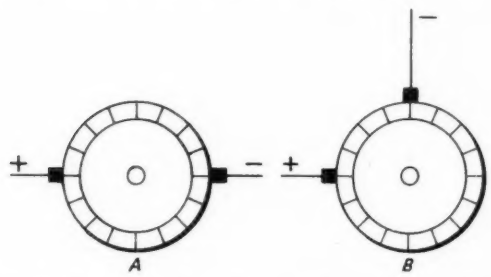


Fig. 3—Lap-winding and wave-winding connections for location of open circuits

the needle would fly right across the scale and the meter would be in danger of being burnt out. This points to a precaution which should be taken when an open coil is suspected. It should first be ascertained that an open circuit does exist, and the meter should be connected to its shunt, or in series with a very high resistance, to limit the amount of current through it to a safe value.

It is possible that at times, instead of a complete break, the deflection across a coil is very high. This is an indication that a high resistance exists in the coil under test. Here the coil ends should be examined at the points where they enter the commutator segments, as there may be an intermittent break, or the ends may have become almost disconnected. The same method can be adopted to locate open or short-circuits in either lap or wave windings. There is only one precaution to be taken; this is to pass current through the armature windings in such a way that there are two circuits in parallel across the testing source of supply. This ensures that the voltage drop across each coil is the same. The method of connection for each case is illustrated in Fig. 3. Here, A shows the connections for a lap winding, and B the connections for a wave winding.

Locating an Earth

The location of the exact point of an earth in an armature winding is not a difficult matter. It is an important test to carry out, since most of the faults can be rectified by merely removing the armature bands, and lifting the earthed coil and renewing a little faulty insulation. A simple method of carrying out the test is illustrated in Fig. 4. Here, M is the meter in series with a battery B and a brush connected to the commutator of the armature to be tested. The battery is earthed on the negative side at E; E_1 is the earthed armature shaft and E_2 is the earth to be located. It will be seen that if E_2 did not exist there would be no current passing from B, because the armature winding is insulated from the shaft.

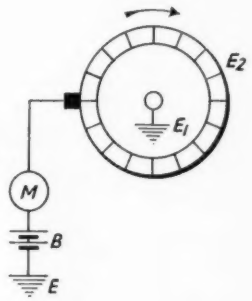


Fig. 4—Diagram illustrating the method of carrying out the location of an earth

When E_2 does exist, there is a circuit from B, through M, to E_2, to E_1, and back to B. The current flowing from B will be indicated on the scale of M, but the reading will vary according to the distance of E_2 from the brush. If, for instance, E_2 is immediately under the brush, the reading on M is at its maximum, because the resistance of the armature coils is not in circuit. If, however, the armature is rotated in the direction of the arrow, E_2 will move further from the brush until, at a point diametrically opposite, maximum resistance is inserted and the deflection on M is at its minimum. If the armature is rotated very slowly and the deflection on M carefully noted, the point of maximum reading should be marked on the commutator segment immediately under the brush, as it is to this segment that the earthed coil is connected.

JAPANESE ELECTRIFICATION.—During the next 18 months the following lines of the Japanese Government Railways are to be electrified on the 1,500-volt d.c. system: the Uyeno-Matsudo section of the Joban line to the north of Tokyo; the freight cut-off line from Shinagawa to Tsurumi on the Tokaido route; and the Maihara-Imanoshe section of the Hokuroku line. Electrification of lines in the Osaka district is also being carried out, and to serve future extensions in this neighbourhood, a new power station is to be erected on the Totsu river at a cost of Y. 20,000,000.

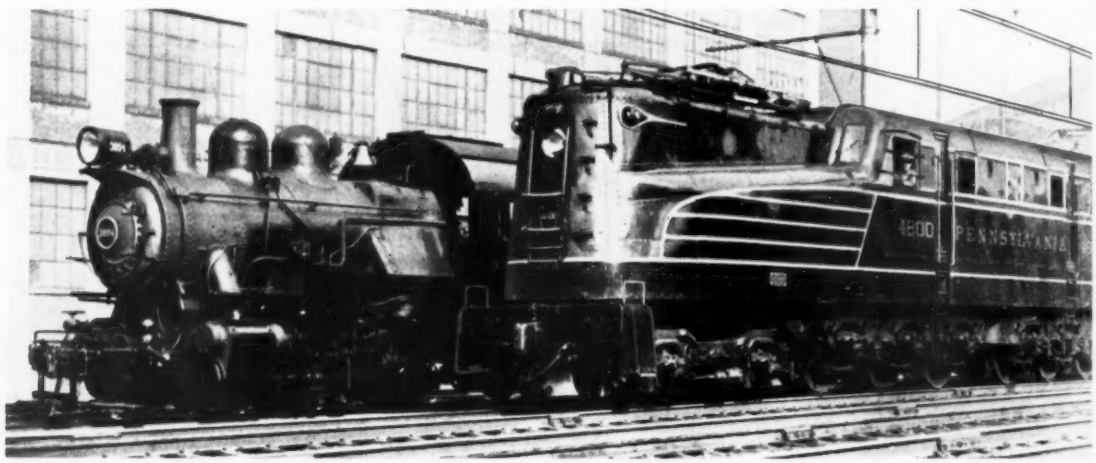
RUSSIAN RECTIFIERS.—For some time past the Soviet electrical industry has been paying increased attention to the production of mercury arc rectifiers, and the first native-built unit was installed at the end of 1933 in a substation on the 1,500-volt Moscow-Sagorsk suburban line. This rectifier was built by the Elektrosila works in Leningrad, and the same factory has since completed a 3,000-volt unit of 2,000 kW. capacity, which is now undergoing trials in one of the first substations of the Moscow-Kursk line, a portion of which is now being converted. It appears from the Russian technical press that a further 20 mercury arc rectifiers are being built in Leningrad for use on various electrified sections of the U.S.S.R. railways. All are of the steel-tank type with rated capacities of 2,000-2,500 kW. at 3,000 volts d.c. output.

NOTES AND NEWS

Swedish West Coast Line.—Electric traction between Malmo and Angelholm, 51 miles, commenced on December 1, and it is expected that the whole 186 miles of the line down the west coast from Malmo to Gothenburg will be operated electrically by the end of next year.

Italian Power Station.—There has just been completed at Suviana, between Florence and Bologna, a hydro-electric station for supplying current to the Direttissima and other lines in central Italy. Current is generated at 6,500 volts and transmitted at 60,000 volts. The cost of the complete power generating equipment was about 120,000,000 lire.

Hastings Electrification.—Mr. C. Grasemann, the Public Relations and Advertising Officer of the Southern Railway, recently stated that the electrification of the line from Wivelsfield via Lewes to Eastbourne and Hastings would enable an average saving of 17 minutes to be made in the journey time from London to Hastings, and give an additional service of 25 trains a day. Mr. Grasemann said he had been asked "why not electrify the direct main line from London?" The company was electrifying the line as far as Sevenoaks, and he hoped that the imagination of his questioner might be right before long.



One of the 4,600 h.p. Pennsylvania Railroad streamlined electric locomotives alongside a steam shunting engine

Pennsylvania Streamlined Locomotives.—As briefly announced in the issue of the *Electric Railway Traction Supplement* for November 16, the Pennsylvania Railroad has ordered 57 streamlined electric locomotives of 4,600 h.p. for service between New York and Washington, with a maximum balancing speed of 90 m.p.h. The accompanying illustration shows one of the trial 2-Co+Co-2 locomotives alongside a steam shunting engine of the 0-6-0 type. The Altoona works of the Pennsylvania will build 18 locomotives; the International G.E.C. will build 14 locomotives and the electrical equipment for nine more; and the Westinghouse Electric & Manufacturing Company will construct the electrical equipment for 34 locomotives. The new machines will be 79½ ft. long, and will have a weight of 205 tons, a driving wheel diameter of 57 in., and a maximum tractive effort of 72,800 lb. They will operate on 11,000-volt 25-cycle single-phase current.

Mersey Improvement Scheme.—The Mersey Railway intends to run six-car trains during rush hours, and six new vehicles, seating 72 passengers in place of the present standard of 64, are to be built. The tunnel on the Liverpool side is to be extended so as to enable six-car trains to be shunted on to the return line at the Central (Low Level) station. Extensions to the platforms at Liverpool (Central) and Green Lane stations are to be made, and all the constructional work will be done by Sir Robert McAlpine & Sons Ltd. It is expected that the complete scheme will cost £25,000.

South Indian Electrification Results.—The working results of the electric train service on the Madras-Tambaram section of the South Indian Railway show that the scheme is a complete success. During the year 1933-34, the average number of tickets sold per week was 137,778, representing an increase of 9·2 per cent. over the previous year, and reached the record figure of 232,870 for the week ending January 6, 1934. A significant feature of the operation of the electrified service lies in the fact that the increase was accompanied by a drop of 16·9 per cent. in the train mileage. The quick and efficient service provided by the electric trains has greatly popularised residence in the suburbs.

Railway Electrification in Poland.—British Insulated Cables Limited, of Prescot, Lancashire, have obtained the contract for the overhead equipment and rail bonding of the first portion of the Polish State Railways, which is being electrified by the English Electric Co. Ltd. and the Metropolitan-Vickers Electrical Co. Ltd. The tracks to be electrified consist of the Warsaw suburban lines, including a complicated system of tracks in Warsaw with 1½ km. of double-track tunnel and double tracks to Zyarow in the southwest, to Otwock in the southeast, and to Nova Minsk in the east, a total track mileage of 155.

The system will be 3,000 volts d.c. and the design of the overhead equipment will include a double contact wire, each wire being supported from the catenary at alternate droppers. The catenaries for each track are to be supported by independent structures with special provision for longitudinal movement of catenary and contact wires due to the wide extremes of temperature obtaining in Poland. The bonds are to be of the welded type attached to the rail head.